Weight loss of litter and cellulose bags in a thinned white spruce forest in interior Alaska

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Thinning in a white spruce, *Picea glauca* (Moench) Voss, forest in interior Alaska stimulated organic matter decomposition in the forest floor as indicated by weight loss of litter and cellulose bags. The general higher weight loss in the most heavily thinned plot is attributed to observed higher average seasonal temperatures. Cellulose bags placed in the boundary between the fermentation–humus and the humus – mineral soil layers of the forest floor showed a significantly higher weight loss than those placed on top of the litter layer. This was attributed to more favorable moisture conditions and a more direct contact with the decomposing microbial populations in the fermentation–humus and humus – mineral soil layers.

Regardless of thinning treatment, elements were grouped according to their rate of release from decomposing organic matter as follows: K > Mg > C ≈ P ≈ N ≈ Ca, where potassium is lease resistant. Since relatively small differences in weight loss of litter bags were observed between the treatments, similar studies should extend over a longer period in order to obtain a better understanding of the decomposition processes.

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Une éclaircie pratiquée dans une forêt d'Epinette blanche, *Picea glauca* (Moench) Voss, de l'intérieur de l'Alaska augmenta la décomposition des éléments organiques de la litière forestière, comme en font foi les pertes de poids de l'humus et des sacs de cellulose. La perte de poids plus élevée dans la plupart des placettes grandement éclaircies est imputable aux températures saisonnières moyennes plus élevées qu'on y a observées. Des sacs de cellulose, placés entre les horizons fermentation–humus et humus – terre minérale de la litière forestière ont indiqué une perte de poids significativement plus grande que ceux placés dans le haut de l'horizon litière. Ce fait est attribué à de meilleures conditions d'humidité et à un contact plus direct avec les populations microbiennes décomposantes se trouvant dans les horizons fermentation–humus et humus – terre minérale.

Quel que fût le traitement d'éclaircie, on peut grouper les éléments selon leurs taux de délivrance des matières organiques énumérés comme suit: K > Mg > C ≈ P ≈ N ≈ Ca (le potassium est le moins résistant). N'ayant pu constater dans les traitements que relativement peu de différences dans la perte de poids subie par les sacs d'humus, il faudrait échelonner des études semblables sur une plus longue période pour mieux comprendre les processus de décomposition.

Introduction

Partially decomposed organic debris which characterizes the upper layer of a forest soil profile is composed for the most part of organic material lost from the trees. Through the process of decomposition, the inorganic and organic chemical elements of the litter are returned to the soil solution. The maintenance of forest soil fertility is largely dependent on this periodic return of plant material, its decomposition, and the release of elements which are important in forest tree nutrition.

Thinning of coniferous forest stands can either increase organic matter decomposition and presumably nutrient availability (Roberge *et al.* 1968) or decrease it (Weetman 1965), depending on changes in chemical, physical, and environmental properties of the forest floor. More research is needed to establish what effects modern sivilcultural practices have on organic matter decomposition in different geographic regions.

A study was initiated in the fall of 1971 in a white spruce forest near Fairbanks, Alaska, with the specific objective of determining the effect of different degrees of thinning on (1) weight loss of organic matter, as indicated by weight loss of litter and standard cellulose bags within and between different

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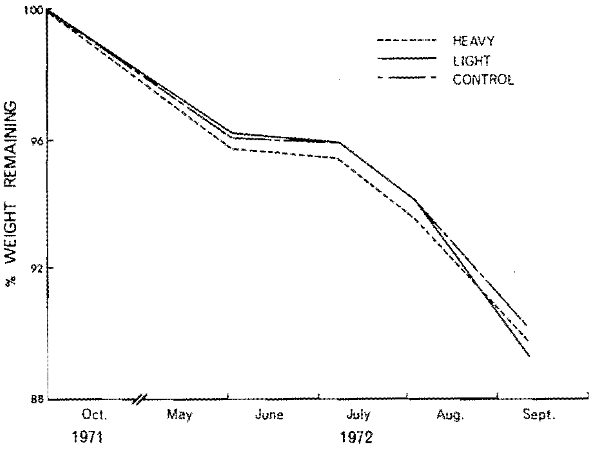

FIG. 1. Percentage of the initial amount of dry matter remaining in white spruce litter bags placed on top of the forest floor in stands subjected to different degrees of thinning.

layers of the forest floor, and (2) the rate of loss of selected nutrient elements from litter bags containing spruce needles.

Materials and Methods

The study area is located on the Yukon–Tanana Upland in a 70-year-old white spruce, *Picea glauca* (Moench) Voss, stand about 30 km west of Fairbanks, Alaska, and is described elsewhere (Van Cleve and Zasada 1976).

In September 1969 and April 1970, three 0.04-ha plots were established and treated as follows: no treatment (control), thinned to 1480 trees/ha (light), and thinned to 740 trees/ha (heavy).

Field Methods

Litter Bags

Samples from the forest floor litter (L) layer were collected from outside the boundary of the control plot. The samples consisted of spruce needles of different ages and states of decomposition. In the laboratory, the needles were separated from the other components of the forest floor, air dried, and thoroughly mixed in a plastic bag. Subsamples were obtained for moisture content determinations and for zero-time nutrient analysis. Twenty grams of needles were put in each nylon bag (mesh size 1 mm^2), and 108 bags (36 in each plot) were placed in the field on top of the L layer on October 1, 1971. Four bags were collected from each plot on June 2, 1972. To decrease the standard deviation, the sampling size was increased to 10 bags from each plot at the next sampling time (July 7). All remaining bags were removed from the field at the last sampling time (September 10). After each sampling, the litter bags were brought to the laboratory in a cooler and stored frozen at −5°C until the samples were analyzed for nutrient elements.

Cellulose Bags

Pulp which contained 93% alpha cellulose was used in this study. The sheets were cut into 5 × 5 cm squares (weighing about 2 g) and placed in nylon bags (mesh size 1 mm^2). Before the bags were placed in the field, they were weighed and subsamples were taken from the original material for zero-time moisture content determinations.

On July 10, 1971, three cellulose bags were put in the forest floor of every subplot (36 subplots, in each of three treatments) in the following manner. A 6.35-cm-diameter core extending to the mineral soil was removed from the forest floor. One bag was placed between the humus layer and the mineral soil (H–M layer), and a second bag was placed in a vertical position on one side of the core hole so that the bag extended from the mineral soil to the surface of the forest floor (F–H layer). The core was then replaced, covering the two bags. A third bag was placed on top of the L layer and was attached to the forest floor with a safety pin.

The first samples from the three plots were collected September 3, 1971. On the first sampling date, four subplots (12 bags) were sampled from each treatment. To decrease the standard deviation, 10 subplots from each treatment were sampled on the remaining sampling dates (June 2, July 10, and September 10, 1972). After each sampling, the cellulose bags were brought to the laboratory in a cooler and stored at −5°C until they were analyzed.

Temperature and Moisture Content Determinations

Temperature and moisture content of the H–M and L layer were measured in the three treatments between May 19 and September 8, 1972. The temperatures, which were recorded during a 1-h period each week, were measured with YSI model 42SC probes. Samples for determination of moisture content were collected using a soil auger and were oven-dried at 60°C for 48 h.

Laboratory Methods

Litter Bags

Needles were separated from the mesh bags, dried for 48 h at 60°C, weighed, and the percent weight loss was determined. The needles subsequently were ground in a Wiley mill using a 40-mesh sieve. According to standard procedures, percent calcium, potassium, and magnesium were determined using an atomic absorption spectrophotometer on aliquots of duplicate nitric–perchloric acid digests of group tissue. Total phosphorus was determined on the same aliquots by the method of Jackson (1958). Total carbon was determined using a Leco automatic carbon analyzer (Tabatabai and Bremner 1970), and Kjeldahl nitrogen, using a microkjeldahl technique (Jackson 1958).

Cellulose Bags

The cellulose was washed according to a standardized IBP procedure (Rosswall 1971), dried in a crucible for 24 h at 60°C, and weighed. The cellulose was then ashed directly in the crucible for 5 h at 700°C and reweighed. Weight loss, determined as percent dry weight of the cellulose, was calculated on an ash-free basis.

Cellulose bags that had been placed in a vertical position in the F–H layer were divided into halves and the percent decomposition was calculated for the two halves for each of the first two sampling dates. This was impossible after the second sampling time because of high cellulose decomposition rates.

Results and Discussion

Weight Changes in Litter and Cellulose Bags

Figure 1 and Table 2 show the weight losses of litter and cellulose bags placed in the different layers of the forest floor in the three experimental plots.

TABLE 1. Effect of thinning on average seasonal temperature and moisture contents in the forest floor L and H–M layers

	Temperature, C°			Moisture, % dry weight		
Layer	Heavy	Light	Control	Heavy	Light	Control
L	22.8±0.2*	20.7±0.1	18.9±0.1	30.9±1.3	38.8±1.5	41.0±1.4
H–M	11.2±0.2	8.9±0.2	10.2±0.2	70.1±2.8	71.4±2.8	53.8±1.8

*95% confidence interval.

TABLE 2. Effect of thinning on average percent weight loss of cellulose bags placed in different forest floor layers

			Percent weight loss		
Sampling time	Days since start of experiment	Plot	L	F–H	H–M
t_1 (Sept. 3, 1971)	55	Heavy	0.07 (0.35)*	18.86 (3.96)	14.99 (4.83)
		Light	1.94 (1.09)	20.62 (6.07)	27.54 (8.41)
		Control	0.74 (2.05)	57.53 (13.53)	46.11 (15.42)
t_2 (June 2, 1972)	328	Heavy	15.80 (3.80)	48.18 (4.40)	43.89 (4.08)
		Light	6.80 (0.95)	63.70 (7.53)	63.60 (10.12)
		Control	5.58 (1.14)	53.03 (7.96)	57.20 (10.22)
t_3 (July 10, 1972)	366	Heavy	20.17 (4.32)	73.12 (3.71)	72.54 (5.79)
		Light	9.50 (3.05)	73.28 (3.92)	74.33 (4.81)
		Control	8.00 (2.32)	53.42 (5.27)	57.36 (7.35)
t_4 (Sept. 10, 1972)	397	Heavy	32.13 (9.21)	79.98 (4.68)	85.84 (3.11)
		Light	23.81 (4.12)	80.70 (7.37)	74.73 (6.00)
		Control	27.70 (7.52)	74.68 (5.44)	75.00 (6.50)

*Standard error in parentheses.

Except for the first sampling time for the cellulose bags, the percent weight loss was consistently higher for the bags placed on top of the L layer in the most heavily thinned plot than for those in the control. Analysis of variance showed that these differences were significant for the first sampling time for the litter bags and for the second and third time for the cellulose bags. No significant difference in weight loss was observed between the most heavily thinned and the lightly thinned plots or between the lightly thinned and the control. For the last three sampling times, a higher weight loss was also observed for the cellulose bags placed in the F–H and H–M layers in the thinned plots, although this was only significant for the F–H layer bags at the third sampling time (Table 2).

A number of factors influence the breakdown of forest floor organic matter in the field. Among these are temperature, moisture, availability of substrate for microbial attack, and the microbial populations present. In the present study the same litter and cellulose were used in all treatments, thus excluding different substrate availabilities between the plots. The observed higher weight loss in the most heavily thinned plot is therefore attributed to higher temperatures in the organic substrate for the L-layer bags and more favorable temperature and moisture regimes for the cellulose bags placed in the F–H and H–M layers (Table 1).

Although obscured by high within-group variances, the results from the litter and cellulose bag study indicate that a higher rate of decomposition of forest floor organic matter occurred in the stand with the heaviest thinning. In contrast, Weetman (1965) noticed an inverse relationship between weight loss of litter bags and thinning treatment in black spruce stands in Quebec. He attributed this to more favorable moisture conditions in the control stand.

Figure 1 shows that after 11 months about 10% weight loss occurred from spruce needles in the control plot. This is a slow rate of decomposition when compared with weight loss rates of 44% for loblolly pine (*Pinus taeda*) after 1 year in Tennessee (Thomas 1968) and of 16–24% for *Pinus densiflora* in Japan (Ando 1970). Probably the cooler drier environment encountered in interior Alaska is responsible for the reduced rate of organic matter decomposition.

Regardless of treatment, the cellulose bags placed in the F–H and H–M layers showed a significantly higher weight loss as compared with the bags placed on top of the L layer (Table 2). This is also indicated by the estimation of the half lives ($T_{\frac{1}{2}}$) (Olson

TABLE 3. Effect of thinning on percent loss of selected elements from litter bags at the last sampling time (after 365 days)

Plot	Ca	N	P	C	Mg	K
Heavy	+5.72 (1.94)*	+3.25 (1.49)	7.02 (5.88)	10.55 (0.89)	26.12 (1.12)	42.42 (4.94
Light	+7.32 (1.08)	+2.54 (1.49)	+2.81 (2.44)	10.52 (0.66)	27.02 (1.28)	31.31 (2.23)
Control	+11.70 (2.18)	0.35 (1.09)	6.53 (6.01)	9.58 (0.93)	22.53 (0.77)	35.81 (4.33)

*Standard error in parentheses.

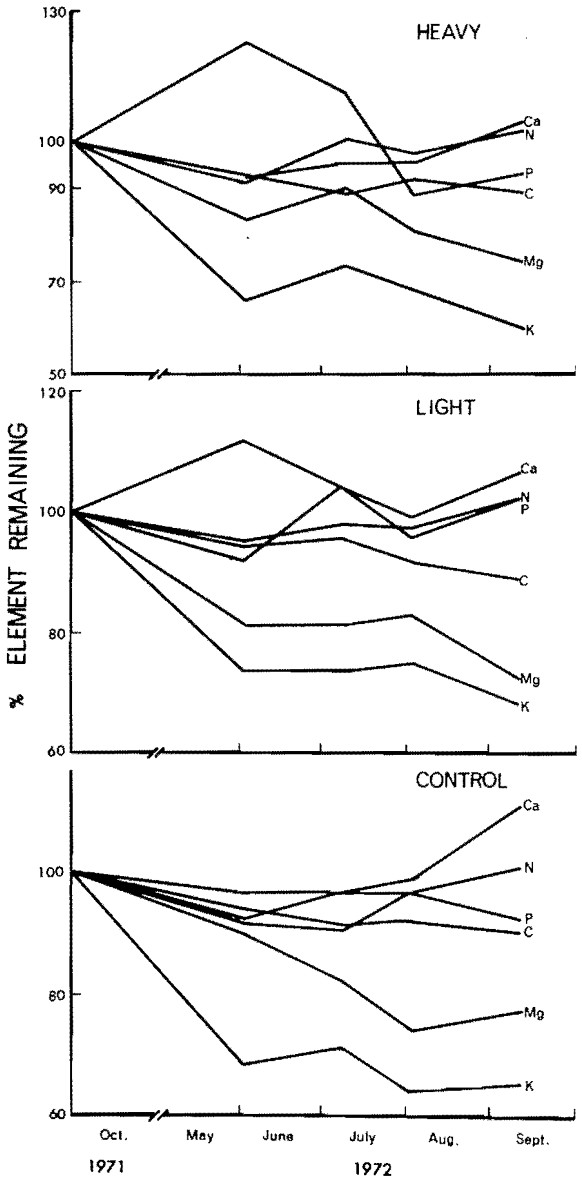

FIG. 2. Percentage of the initial amount of selected chemical elements remaining in white spruce needle litter bags placed on top of the forest floor in stands subjected to different degrees of thinning.

1963) of the cellulose bags in the control, where the bags in the H–M layer had a half life of 212 days as compared with 920 days in the L layer. The observed higher weight loss of bags placed in the F–H and H–M layers is attributed to more favorable moisture conditions and more direct contact between the bags and the microbial populations as compared with those placed on top of the L layer. Similar observations were obtained by Tsarik (1975) where pieces of linen placed in the H–M layer in a *Pinus mugo* forest in the Ukraine showed higher weight loss than those in the forest L layer.

In the present study, cellulose bags placed on top of the L layer decomposed much faster than the litter bags. This is also shown by the estimation of $T_{\frac{1}{2}}$, which was 2.5 years and 6.3 years for cellulose and litter bags, respectively. The lower rate of weight loss in the spruce forest litter probably reflects concentrations of decomposition-resistant lignin and resinous materials as compared with cellulose which has been reported to decompose fairly readily (Sowden and Ivarson 1962).

Chemical Changes in Litter Bags

Regardless of thinning treatment, the rate of release of elements can be grouped as follows: $K > Mg > C \approx P \approx N \approx Ca$, where potassium is least resistant (Fig. 2). Similar trends have been noted for leaves of *Eucalyptus obliqua* by Attiwill (1968) and for *Pinus densiflora* by Katagiri *et al.* (1970).

In analysing the results, it must be kept in mind that when a number of samples is taken from a material in successive stages of decomposition, the changes in percent element composition do not directly give a clear picture of the process of decay. An increase in any one component may mean that the rate of release of this component is less than the overall release of other elements of the organic matter, and does not necessarily represent an increase in the absolute amount. This latter situation can result from input from precipitation (Reiners 1972), or by microorganisms and larger invertebrates that are immobilizing elements to build up their body tissue.

Calcium and nitrogen showed a significant increase in percent composition with time, for all thinning treatments (Fig. 2). The slow release of calcium could be explained by its position in the cell wall which does not break down until a later stage in the decomposition process. The association of nitrogen in proteins which become tannin coated (Davies 1971) and their association with slow-decomposing lignin molecules may explain the slow release of nitrogen.

Percent phosphorus showed no significant change in composition with time, except in the most heavily thinned plot in the early stage of the experimental period (Fig. 2). This may reflect a resistance to breakdown of compounds containing phosphorus, combined with the low weight loss from the litter bags in the initial period of the study.

Percent carbon, magnesium, and potassium showed a significant decrease in percent composition with time (Fig. 2). It is reasonable to expect that magnesium, which is a component of chlorophyll, and potassium, which is an activator for biological reactions, are lost at a more rapid rate than other elements since they are associated with the cytoplasm in the cell. The loss of carbon in the initial stages of decomposition is probably mainly associated with the loss of water soluble carbohydrates as compared with later stages in time of decomposition when compounds like lignin and other cell wall components are exposed to the microbial populations (Bocock *et al.* 1960).

With the exception of nitrogen, a higher percent weight loss of elements was observed from organic matter in the heaviest thinned plot, than in the control (Table 3), although this loss was significant only for magnesium. This is in agreement with a generally higher weight loss of litter bags in this plot as compared with the control. Considering the small weight loss of the litter bags (about 10% at the end of the experimental period), the observed differences in loss of elements between the heaviest thinned and the control plot might be biologically important in determining the effects of thinning on this forest ecosystem.

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